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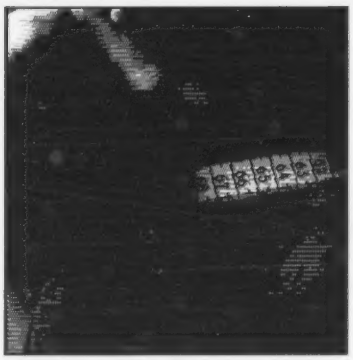

by Margot Shields, Mark S. Tremblay, Sarah Connor Gorber and Ian Janssen

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Abstract

This article describes measures of abdominal obesity—waist circumference, waist-to-hip ratio, and waist-to-height ratio—within body mass index (BMI) categories, using data from two population-based health surveys. Among normal-weight men, the percentages at increased/high health risk based on these three measures were not statistically different in 2007-2009 than in 1981. By contrast, among normal-weight women, increases were observed in the percentage at increased/high health risk based on each of the three measures. The percentage of overweight men at increased/high risk based on waist circumference rose from 49% in 1981 to 62% in 2007-2009, and among overweight women, the percentage at increased/high risk rose for each of the three measures (64% to 93% for waist circumference, 22% to 51% for waist-to-hip ratio, and 68% to 87% for waist-to-height ratio). Although substantial percentages of men and women in obese class I were at increased/high health risk based on abdominal obesity measures in 1981, by 2007-2009, almost everyone in this BMI category was at increased/high risk.

Key words

Body composition, central obesity, waist circumference, waist-to-height ratio, waist-to-hip ratio

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Body mass index (BMI), a measure of weight in relation to height, is the most widely used indicator of obesity. A BMI-based system[1-3] has long been employed to classify adults in categories based on health risk.

In Canada, the prevalence of overweight and obesity is monitored according to this system (Text Table 1). In recent decades, the percentage of Canadian adults classified as having excess weight based on BMI has increased substantially.[4]

Text Table 1
Body mass index (BMI) health risk classification

Category	BMI (kg/m²)	Health risk
Underweight	Less than 18.5	Increased
Normal weight	18.5 to 24.9	Least
Overweight	25.0 to 29.9	Increased
Obese	30.0 or more	
Obese class I	30.0 to 34.9	High
Obese class II	35.0 to 39.9	Very high
Obese class III	40.0 or more	Extremely high

However, criticism of this classification is that it provides no information about the distribution of body fat.[1] Evidence suggests that within the normal, overweight and obese class I categories, health risk rises with the level of abdominal obesity.[5,6] Consequently, several organizations, including Health Canada, have recommended that a combination of BMI and waist circumference be used to classify weight-related health risk.[1,2,7]

Recent research has found that, on average, the waist circumference of Canadian adults with a given BMI value is now larger than in the past,[8] similar to findings for the United States.[9] Therefore, it is important to measure and monitor abdominal obesity within BMI categories.

This article documents changes in obesity indicators between 1981 and 2007-2009 in Canadians aged 20 to 69 years, based on measured data collected in two population-based health surveys (see *The data*). The primary objective was to examine changes in abdominal obesity within BMI categories, based on waist circumference, waist-to-hip ratio, and waist-to-height ratio.

Adiposity measures increase

Among men and women, all four adiposity measures increased significantly between 1981 and 2007-2009 (Table 1). However, the pattern of change differed by BMI category.

Among men in the normal-weight category, the means for the four adiposity measures were not statistically different at the two time points. By contrast, among women in the normal-weight category, mean BMI rose by 0.2 kg/m^2, and waist circumference, by 4 cm. Significant increases were also observed for waist-to-hip ratio and waist-to-height ratio.

Among those in the overweight category, a significant increase in mean BMI was observed for both sexes. Increases in means for abdominal obesity were particularly notable among overweight women: 7 cm for waist circumference; 0.05 for waist-to-hip ratio; and 0.03 for waist-to-height ratio. Among overweight men, the increases were 2 cm for waist circumference and 0.01 for waist-to-hip ratio; the increase for waist-to-height ratio did not attain statistical significance.

Increases in abdominal obesity measures tended to be greatest for people in the obese categories. For instance, the increase in waist circumference was 11 cm among class II/III men, and 9 cm among class II/III women.

Health risk categories

Health risk ratings for the obesity indicators are presented in Table 2. Ratings for the abdominal obesity indicators are provided within the BMI categories for normal weight, overweight and obese class I. Rating are not presented for obese class II/III, because in both 1981 and 2007-2009, nearly all adults in these categories were at increased/high risk according to the abdominal obesity indicators (data not shown).

Among normal-weight men, the percentages at increased/high health risk based on their waist circumference, waist-to-hip ratio and waist-to-height ratio were not statistically different in 2007-2009 than in 1981. By contrast, among normal-weight women, the percentage at increased/high risk according to each of these measures was approximately three times higher in 2007-2009 than in 1981. Based on their waist circumference, the percentage of normal-weight women at increased/high risk rose from 8% to 23%. The corresponding increases were from 6% to 16% for waist-to-hip ratio, and from 6% to 18% for waist-to-height ratio.

In 2007-2009, 62% of overweight men were at increased/high health risk based on their waist circumference, up from 49% in 1981; the percentage at *high* risk rose from 8% to 20%. However, the percentage of overweight men at increased/high risk based on their waist-to-hip ratio and waist-to-height ratio was not different at the two time points. Based on their waist circumference, 54% of overweight women were at high risk in 2007-2009, up from 17% in 1981.

The data

Current estimates are from the 2007-2009 Canadian Health Measures Survey (CHMS),[10] which collected data at 15 sites across the country from March 2007 through February 2009. The survey covered the household population aged 6 to 79 years. Full-time members of the Canadian Forces and residents of Crown lands, Indian reserves, institutions and certain remote regions were excluded. The sample represented approximately 96% of the population. In addition to a questionnaire, the survey involved physical measures (including height, weight, waist circumference, and hip circumference) at a mobile examination centre. The CHMS estimates in this article are based on 3,074 respondents aged 20 to 69 years. Of the households selected, the response rate was 69.6%. One or two members of each responding household were chosen to participate: 87.6% of selected 20- to 69-year-olds completed the household questionnaire, and 83.6% of these respondents completed the physical examination. The overall combined response rate was 51.0%.

Historical estimates are based on the 1981 Canada Fitness Survey (CFS),[11] which collected data from a nationally representative sample of the population between February and July 1981. The sample consisted of 13,500 households. The overall response rate for the physical measures component of the survey was 49%. The CFS estimates in this article are based on 10,605 respondents aged 20 to 69 years.

Pregnant women were excluded from both data sources.

Each survey measured weight to the nearest 0.1 kg, and height, to the nearest 0.1 cm. Waist circumference was measured at the end of a normal expiration to the nearest 0.1 cm at the mid-point between the last floating rib and the top of the iliac crest.[12,13] Hip circumference was measured at the level of the symphysis pubis and the greatest gluteal protuberance.[12]

Body mass index (BMI) was calculated as weight in kilograms divided by height in metres squared (kg/m^2); waist-to-hip ratio as waist circumference in cm divided by hip circumference in cm; and waist-to-height ratio as waist circumference in cm divided by height in cm.

Based on categories recommended by the World Health Organization,[13] Health Canada[1] and Obesity Canada,[2] respondents were divided into the six BMI-based health risk categories (underweight, normal weight, overweight, and obese class I, II and III) and three categories based on waist circumference: low-risk (men, 93.9 cm or less; women, 79.9 cm or less), increased-risk (men, 94.0 to 101.9 cm; women, 80.0 to 87.9 cm), and high-risk (men, 102.0 cm or more; women, 88.0 cm or more). In accordance with recommended cut-points, respondents were also classified as being at increased/high risk based on waist-to-hip ratio (men 0.9 or more; women 0.85 or more)[3] and waist-to-height ratio (0.5 or more for both sexes).[14]

All analyses were weighted to obtain estimates representative of the Canadian population. Estimates based on the CFS were age-standardized to the 2007-2009 population to account for shifts in Canada's age distribution during this period.

Statistical analyses were performed using SAS and SUDAAN software. Standard errors, coefficients of variation, and 95% confidence intervals for CHMS estimates were calculated with the bootstrap technique.[15,16] The number of degrees of freedom was specified as 11 to account for the CHMS sample design.[10] Estimates of sampling error for the CFS estimates were based on formulae for simple random sampling with the incorporation of a design effect of 1.5 to account for the complex design of the survey. Significant differences between means and prevalence estimates across surveys were assessed using t-tests.

Table 1
Means for adiposity measures, by body mass index (BMI) category and sex, household population aged 20 to 69 years, Canada, 1981 and 2007-2009

	Men						Women					
	1981			2007-2009			1981			2007-2009		
		95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval	
	Mean	from	to	Mean	from	to	Mean	from	to	Mean	from	to
Total												
Body mass index (kg/m²)	25.5	25.3	25.6	27.6*	27.2	28.0	24.1	23.9	24.4	26.8*	26.0	27.6
Waist circumference (cm)	89.4	88.9	89.9	95.9*	94.6	97.3	76.3	75.8	76.8	86.9*	84.7	89.1
Waist-to-hip ratio	0.90	0.90	0.90	0.93*	0.92	0.94	0.77	0.77	0.78	0.83*	0.82	0.84
Waist-to-height ratio	0.51	0.51	0.52	0.55*	0.54	0.55	0.48	0.47	0.48	0.54*	0.52	0.55
Normal weight (BMI 18.5 to 24.9 kg/m²)												
Body mass index (kg/m²)	22.7	22.6	22.8	22.9	22.6	23.1	21.9	21.8	22.0	22.1*	22.0	22.3
Waist circumference (cm)	82.2	81.8	82.6	82.5	81.6	83.4	71.4	71.1	71.8	75.7*	74.8	76.7
Waist-to-hip ratio	0.87	0.86	0.87	0.87	0.86	0.87	0.75	0.75	0.76	0.79*	0.78	0.80
Waist-to-height ratio	0.47	0.47	0.47	0.47	0.47	0.48	0.44	0.44	0.45	0.46*	0.46	0.47
Overweight (BMI 25.0 to 29.9 kg/m²)												
Body mass index (kg/m²)	27.1	27.0	27.2	27.5*	27.2	27.7	26.9	26.8	27.1	27.4*	27.1	27.6
Waist circumference (cm)	93.8	93.3	94.2	96.1*	95.1	97.1	82.5	81.9	83.2	89.2*	88.1	90.4
Waist-to-hip ratio	0.92	0.92	0.93	0.93*	0.93	0.94	0.80	0.79	0.80	0.85*	0.84	0.86
Waist-to-height ratio	0.54	0.54	0.54	0.55	0.54	0.55	0.52	0.52	0.52	0.55*	0.54	0.56
Obese class I (BMI 30.0 to 34.9 kg/m²)												
Body mass index (kg/m²)	31.5	31.3	31.7	32.0*	31.7	32.3	32.0	31.8	32.3	32.2	31.9	32.5
Waist circumference (cm)	104.2	103.3	105.2	108.0*	106.6	109.4	93.5	92.0	95.0	100.7*	99.2	102.2
Waist-to-hip ratio	0.96	0.95	0.97	0.99*	0.98	1.00	0.84	0.82	0.85	0.89*	0.87	0.90
Waist-to-height ratio	0.60	0.60	0.61	0.62*	0.61	0.63	0.59	0.58	0.60	0.62*	0.61	0.63
Obese class II/III (BMI 35.0 kg/m² or more)												
Body mass index (kg/m²)	37.6	36.2	39.1	39.6*	38.5	40.7	38.5	37.5	39.5	39.5	38.9	40.0
Waist circumference (cm)	115.9	112.3	119.5	126.5*	123.6	129.4	104.1	101.5	106.7	113.5*	112.2	114.8
Waist-to-hip ratio	0.97	0.95	1.00	1.03*	1.01	1.04	0.85	0.80	0.89	0.89	0.88	0.89
Waist-to-height ratio	0.67	0.66	0.69	0.72*	0.70	0.74	0.66	0.64	0.67	0.71*	0.70	0.72

* significantly different from 1981 ($p<0.05$)
Note: 1981 estimates were age-standardized to 2007-2009 population.
Sources: 1981 Canada Fitness Survey; 2007-2009 Canadian Health Measures Survey.

The percentage of overweight women at increased/high risk based on their waist-to-hip ratio more than doubled from 22% to 51%, and the percentage at increased/high risk based on their waist-to-height ratio rose from 68% to 87%.

In 1981, 62% of men and 82% of women in obese class I were classified at high health risk based on their waist circumference; by 2007-2009, the percentages had risen to 84% and 94%, respectively. Based on their waist-to-hip ratio, the percentage of obese class I men at increased/high risk rose from 90% to 96%; among women, the figure rose from 48% to 75%. At both time points, virtually all men and women in obese class I were classified at increased/high risk based on their waist-to-height ratio.

Shifting distributions

Figure 1 illustrates shifts in the distribution of waist circumference measurements toward the higher risk ranges among people in the normal-weight, overweight and obese class I categories. While the distributions in 1981 and 2007-2009 among normal-weight men were virtually the same, a shift among normal-weight women meant that a higher percentage of them had waist circumferences that put them in the increased and high-risk ranges. Among overweight people of both sexes, there was a shift to larger waist circumferences, on average, particularly among women. For men and women in obese class I, most of the waist circumference distribution fell beyond the high-risk cut-point in 1981. Nonetheless, there was a pronounced shift to even larger waist circumferences, on average, by 2007-2009.

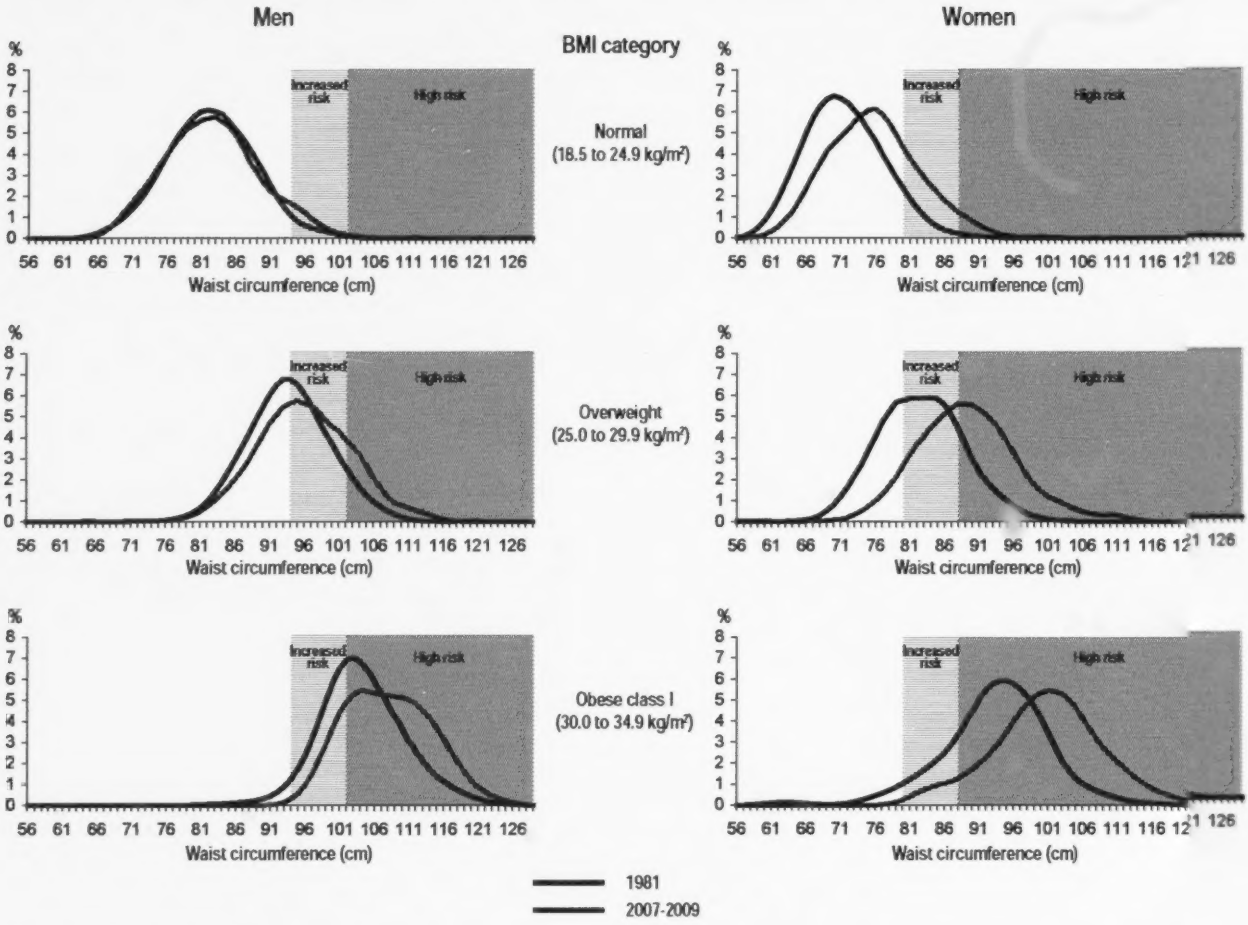
Trends in the distributions for waist-to-hip ratio and waist-to-height ratio measurements within BMI categories were similar (data not shown). As well, the distribution of BMI values within BMI categories shifted toward higher values. For example, among normal weight women, the percentage whose BMI was at the high end of the category (24 kg/m² or more) rose from 13% in 1981 to 21% in 2007-2009.

Table 2
Percentage distribution of adiposity health risk variables, by sex and body mass index (BMI) category, household population aged 20 to 69 years, Canada, 1981 and 2007-2009

	Body mass index category																	
	Total				Normal				Overweight				Obese class 1					
	1981			2007-2009			1981			2007-2009			1981			2007-2009		
	%	95% confidence interval from	to	%	95% confidence interval from	to	%	95% confidence interval from	to	%	95% confidence interval from	to	%	95% confidence interval from	to	%	95% confidence interval from	to
Men																		
BMI category																		
Underweight	1.2[E]	0.8	1.8	0.8	0.4	1.5	...	...	...	...	...	...	...	...	...	...	...	...
Normal	46.3	43.9	48.8	30.5*	25.5	36.0	...	...	...	...	...	...	...	...	...	...	...	...
Overweight	42.4	39.9	44.9	44.1	39.0	49.3	...	...	...	...	...	...	...	...	...	...	...	...
Obese class I	8.6	7.2	10.2	17.8*	14.6	21.5	...	...	...	...	...	...	...	...	...	...	...	...
Obese class II or III	1.5[E]	1.0	2.2	6.9*	5.9	8.0	...	...	...	...	...	...	...	...	...	...	...	...
Waist circumference health risk																		
Low	68.2	65.7	70.6	46.3*	41.6	51.1	97.0	95.4	98.1	93.7	89.3	96.4	51.5	47.4	55.5	38.5*	31.4	46.0	F	...	...	F	...	...
Increased	21.8	19.7	24.1	23.0	19.4	27.0	3.0[E]	1.9	4.6	6.2[E]	3.5	10.7	40.9	37.0	45.0	41.4	35.5	47.4	35.6	27.7	44.4	16.1*[E]	8.7	27.9
High	10.0	8.5	11.8	30.7*	25.6	36.3	F	...	...	F	...	...	7.6	5.7	10.2	20.2*	15.3	26.2	62.1	53.4	70.2	83.9*	72.1	91.3
Increased/High	31.8	29.4	34.3	53.7*	48.9	58.4	3.0[E]	1.9	4.6	6.3[E]	3.6	10.7	48.5	44.5	52.6	61.5*	54.0	68.6	97.7	95.4	98.9	100.0	...	...
Waist-to-hip ratio health risk																		
Low	48.4	45.9	50.9	35.6*	31.7	39.7	71.3	67.7	74.6	71.8	63.1	79.1	30.9	27.6	34.4	28.0	23.5	32.9	10.4[E]	6.4	16.6	F	...	...
Increased/High	51.6	49.1	54.1	64.4*	60.3	68.3	28.7	25.4	32.3	28.2	20.9	36.9	69.1	65.6	72.4	72.0	67.1	76.5	89.6	83.4	93.6	96.3*	90.0	98.7
Waist-to-height ratio health risk																		
Low	41.6	39.3	44.0	30.4*	26.0	35.2	76.5	73.0	79.7	79.7	75.2	83.5	11.7	9.9	13.8	12.2	8.9	16.6	F	...	...	F	...	...
Increased/High	58.4	56.0	60.7	69.6*	64.8	74.0	23.5	20.3	27.0	20.3	16.5	24.8	88.3	86.2	90.1	87.8	83.4	91.1	99.7	97.0	100.0	100.0	...	...
Women																		
BMI category																		
Underweight	3.4	2.8	4.2	2.3	1.3	4.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Normal	62.2	59.7	64.7	44.7*	37.7	51.9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Overweight	24.8	22.6	27.2	28.9*	25.7	32.3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Obese class I	7.1	5.8	8.6	12.4*	10.0	15.4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Obese class II or III	2.4[E]	1.7	3.5	11.6*	8.4	16.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Waist circumference health risk																		
Low	70.1	67.7	72.5	39.0*	32.6	45.8	92.5	90.5	94.1	77.2*	69.6	83.3	35.6	30.4	41.2	7.5*[E]	4.2	13.3	F	...	...	F	...	...
Increased	17.1	15.2	19.2	20.3	16.8	24.4	6.9	5.3	8.8	19.1*	13.6	26.1	47.7	42.2	53.2	38.4*	31.8	45.5	14.0[E]	8.9	21.3	F	...	...
High	12.8	11.0	14.7	40.6*	34.5	47.0	F	...	...	3.8*[E]	2.6	5.6	16.7	13.0	21.2	54.1*	46.1	61.8	81.6	73.2	87.9	94.3*	85.2	97.9
Increased/High	29.9	27.5	32.3	61.0*	54.2	67.4	7.5	5.9	9.5	22.8*	16.7	30.4	64.4	58.8	69.6	92.5*	86.7	95.8	95.7	88.2	98.5	100.0	...	...
Waist-to-hip ratio health risk																		
Low	86.4	84.4	88.2	60.4*	55.1	65.6	94.5	92.6	95.9	84.2*	77.8	89.0	77.8	72.9	82.1	48.9*	42.5	55.3	52.2	42.0	62.2	24.7*[E]	16.6	35.1
Increased/High	13.6	11.8	15.6	39.6*	34.4	44.9	5.5	4.1	7.4	15.8*	11.0	22.2	22.2	17.9	27.1	51.1*	44.7	57.5	47.8	37.8	58.0	75.3*	64.9	83.4
Waist-to-height ratio health risk																		
Low	69.8	67.3	72.3	43.3*	37.6	49.1	93.7	91.7	95.2	82.3*	77.5	86.3	32.1	27.5	37.2	13.0*[E]	8.6	19.3	F	...	...	F	...	...
Increased/High	30.2	27.7	32.7	56.7*	50.9	62.4	6.3	4.8	8.3	17.7*	13.7	22.5	67.9	62.8	72.5	87.0*	80.7	91.4	97.8	93.8	99.2	97.5	80.0	99.7

* significantly different from 1981 ($p<0.05$)
[E] use with caution
F too unreliable to be published
... not applicable
Note: 1981 estimates were age-standardized to 2007-2009 population.
Sources: 1981 Canada Fitness Survey; 2007-2009 Canadian Health Measures Survey.

Figure 1
Percentage distribution of waist circumference, by body mass index category (BMI), household population aged 20 to 69 years, Canada, 1981 and 2007-2009



Note: 1981 estimates were age-standardized to 2007-2009 population.
Sources: 1981 Canada Fitness Survey; 2007-2009 Canadian Health Measures Survey.

Conclusion

Current surveillance of obesity in Canada relies almost exclusively on BMI. This study reveals that abdominal obesity within BMI categories is increasing. As a result, Canadians with a given BMI are, on average, at higher risk of obesity-related health conditions than they were in 1981. The Canadian body weight classification system and the Canadian clinical practice guidelines recommend that adults' waist circumference also be measured to assess obesity-related health risks .[1,2] The results of this study underscore the importance of measuring and monitoring abdominal obesity within BMI categories. ■

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